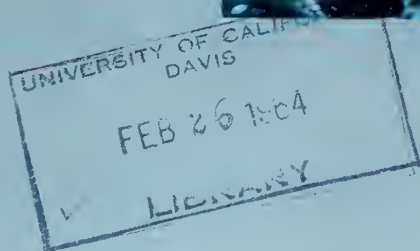


*Franciscan Ship, Sciences Club,
No. 1*

Age and Structural Relationships of the

Franciscan Formation

in Montara Mountain Quadrangle



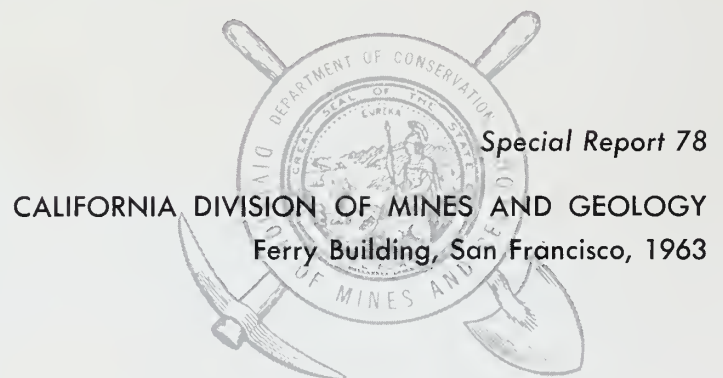
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Special Report 78

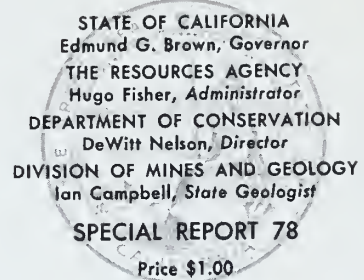
Cover photograph: Point San Pedro, San Mateo
County. Photo by C. W. Jennings and R. G. Strand.

Age and Structural Relationships of the FRANCISCAN FORMATION IN THE MONTARA MOUNTAIN QUADRANGLE

San Mateo County, California

By RICHARD L. DARROW, Geologist
Standard Oil Company of California
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CONTENTS

Page	
5	Preface
7	Abstract
9	Introduction
9	Descriptive geology
9	Montara granodiorite
11	Franciscan formation
16	Late Upper Cretaceous rocks
17	Paleocene rocks
19	Structural geology
19	Folding
20	Faulting
21	Subsidence
21	Geologic history
22	Bibliography

Illustrations

In pocket	Plate	1.	Geologic map of northwest part of Montara Mountain quadrangle
In pocket	Plate	2.	Structure sections across Montara Mountain quadrangle
10	Figure	1.	Index map showing location of Montara Mountain quadrangle and the area mapped for this report
11	Figure	2.	Diagrammatic section of rocks in Montara Mountain quadrangle
14	Figure	3.	Drawings of thin sections
12	Photo	1.	Unconformity between Paleocene and Upper Cretaceous rocks
13	Photo	2.	San Pedro Rock and its relationship to the mainland
17	Photo	3.	The mainland from San Pedro Rock, showing Upper Cretaceous and Paleocene rocks
17	Photo	4.	Overtured Upper Cretaceous strata
18	Photo	5.	Gneissic boulder from Sur series terrane
18	Photo	6.	Paleocene basal conglomerate
19	Photo	7.	Landslide on Highway 1
19	Photo	8.	Local contortions in Paleocene rocks
20	Photo	9.	Fault in Paleocene rocks
21	Photo	10.	Thrust fault through granodiorite

PREFACE

This paper is essentially the master's thesis of Richard L. Darrow, University of California, 1951, on *Geology of the Montara Mountain area, San Mateo County, California*. The area mapped and described includes San Pedro Point, San Pedro Valley, Montara Mountain, and the triangular wedge of Franciscan rocks between the Pilarcitos and San Andreas fault zones. The area is part of the San Francisco peninsula—type locality of the Franciscan "series" of Lawson, a formation long regarded as Late Jurassic. Pollen collected from the Franciscan shale by Mr. Darrow provides an age criterion heretofore not applied to the Franciscan. Dating of the pollen as mid-Cretaceous is consistent with evidence of age from foraminifera and an ammonite found on the San Francisco peninsula. Although unpublished, Mr. Darrow's thesis has been on open file at the Division of Mines in San Francisco and has been frequently consulted by geologists and cited in the literature.

GORDON B. OAKESHOTT
San Francisco, December 1960



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ABSTRACT

The area mapped and described in this paper lies within the Montara Mountain quadrangle, on the San Francisco peninsula, in San Mateo County, California. The Cretaceous-Paleocene rocks of the region comprise the Franciscan Formation, the Montara granodiorite, a late Upper Cretaceous sedimentary unit, and a Paleocene unit. The sedimentary units have been complexly folded and faulted between the Pilarcitos thrust fault on the southwest and the San Andreas fault on the northeast.

The San Francisco peninsula is the type locality of Lawson's (1895) Franciscan "series", long regarded as Late Jurassic in age. However, pollen—dated as mid-Cretaceous—has been collected from the Franciscan shale in the Montara Mountain quadrangle, supporting previous evidence (provided by foraminifera and an ammonite) of the mid-Cretaceous age of this part of the Franciscan Formation.

AGE AND STRUCTURAL RELATIONSHIPS OF THE FRANCISCAN FORMATION IN THE MONTARA MOUNTAIN QUADRANGLE

San Mateo County, California*

By RICHARD L. DARROW

INTRODUCTION

The area studied for this report lies within the Montara Mountain quadrangle, in San Mateo County, California. It is a 26-square-mile pentagonal area, bordered on the north by the northern boundary of the quadrangle, on the northeast by State Highway 5 (Skyline Boulevard), on the southeast by a northeast-trending line stretching between Montara Mountain and Buri Buri Ridge, on the southwest approximately by the crest of Montara Mountain, and on the northwest by the Pacific Ocean. The communities of Vallemar, Rockaway Beach, and San Pedro Valley are within it, and San Francisco lies 14 miles to the north.

The base used in mapping was the U.S. Geological Survey topographic sheet published in 1949 and drawn on a scale of 1:24,000. This is the most northwesterly of four 7½-minute quadrangles, which together make up the same areas the older San Mateo 15-minute quadrangle published in 1892.

San Pedro and Calera Valleys are partly submerged, recently aggraded, formerly youthful valleys. Farther inland the terrain, which has been rejuvenated from a former partially peneplaned surface, is rugged. Some of the tributary stream grades show as much as 75-foot drops in a distance of 100 feet, giving rise to cataracts and small falls. The remnants of an old surface lie at elevations between 1100 and 1300 feet. Montara Mountain is a rising land mass with an elevation of 1898 feet. The area includes many natural divides; some have been formed by differential weathering of lithologic units, but most have been established by relatively rapid erosion of thrust-fault zones in contrast to inter-thrust masses. Topographic features so developed are particularly noticeable in the northeastern part of the area.

The annual rainfall over the San Francisco peninsula varies between 25 and 45 inches, decreasing somewhat inland. Pilarcitos Lake, for example, receives an average of 10 inches more rain per year than San Andreas Lake. The few permanent streams present have headwaters on Montara Mountain. Average monthly temperatures range from 37° F in January to 54° F in August. Northern and eastern slopes support thick brush and trees.

Previous Work. Pioneer geologic work on the Montara Mountain area was done by Lawson (1895) prior to 1894. His geologic map was published in 1914. Some detailed work has been done by Walker (1950) on certain of the lithologic units.

Acknowledgments. The author is indebted to the late Dr. N. L. Taliaferro for advice given during progress of this work, and to C. M. Gilbert who criticized the geologic map. He is also grateful to J. W. Durham, who spent many hours in the field and laboratory on fossils collected during this study, to H. P. Hansen of Oregon State College, who identified specimens of fossil pollen; and to Ralph W. Chaney, who has helped to interpret these identifications. The writer thanks A. S. Campbell of St. Mary's College for his statement concerning the foraminiferal genus *Globotruncana*. Financial assistance from the research fund of the Department of Geological Sciences of the University of California is gratefully acknowledged.

DESCRIPTIVE GEOLOGY

Montara Granodiorite

Montara granodiorite forms the southwestern margin of the area mapped. It was considered by Lawson to be older than the Franciscan formation and intrusive into the crystalline limestone of unknown age that is found farther south.¹

The granodiorite commonly is coarse-grained, having feldspar crystals ¼ to ½ inch in longest dimension. Biotite is usually present and quartz is abundant. Pegmatitic veins are common as are hornblende-rich intrusions; hornblende is conspicuously absent in the main granitic mass.

The composition of the Montara granodiorite is variable, ranging from quartz diorite to acid granite. An average composition at the Devil's Slide area along State Highway 1 as determined from a number of thin sections, is:

* Modified from Master's thesis, Department of Geological Sciences, University of California, Berkeley. Original manuscript submitted for publication April 1951.

¹ K-A dates obtained by Curtis, Evernden, and Lipson (1958) suggest the granitic rock is Late Cretaceous in age and is therefore probably post-Franciscan.—Ed.

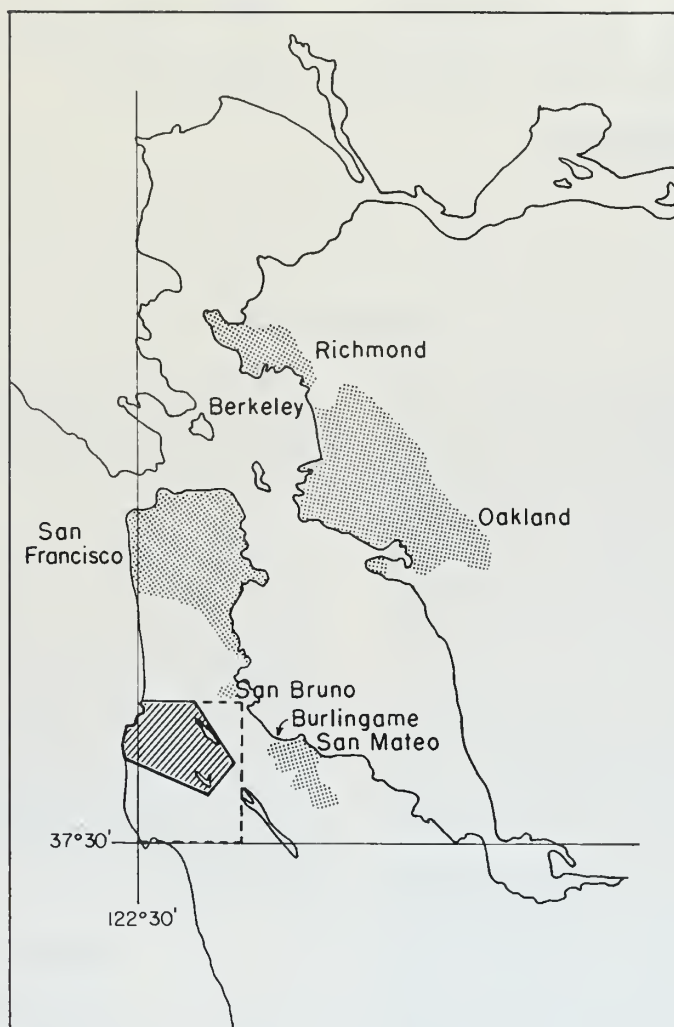


FIGURE 1. Index map showing location of the Mantara Mountain 7½' quadrangle (dashed lines), and the area covered by the geologic map accompanying this report (hachured).

	Percent
Oligoclase	50
Orthoclase	25
Quartz	20
Green biotite	4
Granular sphene	1

In these sections the oligoclase crystals average $2\frac{1}{2}$ millimeters in diameter; biotite crystals are of similar dimensions; quartz and alkali feldspar average $1\frac{1}{2}$ millimeters in size. There is an increasing abundance of vein quartz in the higher peaks of Montara Mountain. Bodies of milky quartz are present which are extensive enough to have been prospected for metals.

Pilarcitos Dam is flanked on the southwest by a mass of the Montara granodiorite. Farther west another smaller mass occurs; the position of both masses is the result of extreme faulting. Examination of thin sections of specimens from these bodies showed their composition to be similar to that of the main granodiorite mass.

Franciscan Formation

The segment of the Franciscan formation studied in this survey is a small part of the Franciscan terrane of Lawson. This particular area, which is part of the Franciscan type area (Lawson, 1895) is a portion of a belt of sediments that has been mapped from the Golden Gate southward to the New Almaden district. While many lithologic characteristics of the belt are identical with those of Franciscan units of other localities, some differ significantly.

In this study, the Franciscan is mapped as sandstone, Calera limestone, chert, and basalt, intruded by serpentine and diabase. The author believes that variations within the sandstone and basalt beds of the Franciscan can be mapped by petrographic research; for example, sandstone beds present on the crest of Cattle Hill can be differentiated from those of Buri Buri Ridge by their tuffaceous character.

Sandstone. The great bulk of the sandstone of this area is massive, coarse to fine grained with local shale and conglomerate lenses.

Taliaferro (1943) in his extensive work on the Franciscan sandstone has described it generally as an arkose in which the feldspar content ranges from about 30 to 60 percent. He reported the plagioclase to be predominantly oligoclase-andesine, although more calcic varieties are present. He also reported orthoclase as a common constituent, microcline rare; quartz as always being present, and not infrequently predominating.

In the area under discussion, the sandstone is invariably a graywacke in which lithic fragments predominate. The plagioclase content rarely exceeds 25 percent and is nearly always oligoclase. Orthoclase is rare and microcline has not been noted.

In surface exposures the sandstone is commonly weathered to depths of 50 feet or more on account of its crushed and hence porous nature. A few places, however, have been found where unweathered samples can be collected. The most accessible place is in the quarry just north of San Andreas Dam. The crushed nature of the sandstone at this location is not necessarily due to its proximity to the San Andreas fault, for crushing is a characteristic of the Franciscan sandstones of the entire area. With the unaided eye this sandstone is easily mis-

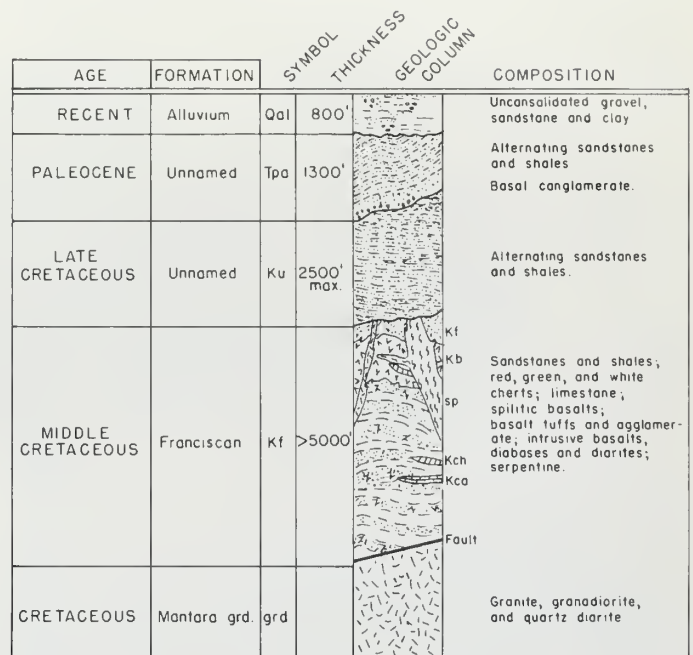


FIGURE 2. Diagrammatic section of rocks in the Montara Mountain quadrangle.

taken for a fine-grained igneous rock. It is crushed throughout, and pieces larger than 2 or 3 inches across are rare. Secondary calcite is commonly the cementing agent. The principal constituents are:

	Percent
Rock fragments and clay	40
Quartz	30
Oligoclase	25
Biotite and muscovite	2
Sphene (granular)	1
Augite	less than 1
Traces of: garnet, epidote, calcareous fossiliferous material, potash feldspar.	

Rock fragments include fine sandstone, chert, mica schist, black slate, and spilitic basalt. The quartz fragments, like all of the constituents of the graywacke, are angular, many of them displaying delicate points. The oligoclase is fresh and most of it exhibits polysynthetic twinning. The augite is colorless and has optical properties identical with the augite in the associated basalts found in this area.

Sandstone from localities other than that near San Andreas Dam contains as little as 15 percent quartz and as much as 45 percent rock fragments. Calcite is common in small amounts as a secondary mineral, and the tuffaceous content rises to 10 percent in some samples.

Shale and conglomerate make up between 1 and 5 percent of the clastic sediments of the series. A small lens of conglomerate is present 1,500 feet east of the northeast tip of Pilarcitos Lake. It is composed of dark and light well-rounded chert fragments in a matrix of coarse sandstone. This conglomerate has been well compacted, but not to the extent of distorting the pebbles. Shale is local, thin-bedded, and is always found sheared between massive sandstone beds.

The sandstone beds of this area are graywacke of the type described by Dapples, Krumbein, and Sloss (1948), as belonging to the geosynclinal facies of sedimentation. Considering the available information concerning the mineralogy and angularity of the constituents, the author's conclusions parallel those of Taliaferro (1943) who states that:

... much of the Franciscan was derived from a high and rugged terrain, which lay to the west of the present coast line, under rather rigorous climatic conditions, probably heavy precipitation, and a cold climate in the highlands. Mechanical disintegration clearly predominated over chemical decomposition in the rugged area from which the Franciscan was derived.

Apparently the sandstone beds of this region are derived from more siliceous rocks than the average Franciscan sediments, and contain a much smaller shale fraction than most Franciscan clastics.

Calera Limestone. The Calera limestone was named from its type area in Calera Valley, Rockaway Beach, and was originally described by Lawson as a member of the "Cahil" sandstone, the oldest division of his Franciscan "series". From its type locality the Calera limestone is found in discontinuous outcrops which extend southeastward to Santa Clara County. G. W. Walker (1950) states that all of the limestone between the San Andreas and Pilarcitos faults has been broken into a series of fault slivers that are suspended in sheared and plastically deformed sedimentary material and greenstone. The writer does not believe that this is the case, for the bulk of the limestone found in this area is in two characteristic zones; one zone is associated only with sandstone; the other is associated with sandstone and basalt.

The lower zone crops out on the hill above Sanchez Adobe, in the southeast end of San Pedro Valley, and on the western side of Spring Valley Ridge. South of this point it does not crop out, as it has been cut off by the Pilarcitos thrust. This zone is, in part, associated with intrusive rocks and faulting. The second zone is found as discontinuous outcrops from Rockaway Beach southeast through the center of the area to Pilarcitos Lake and beyond. It also is associated with faulting locally, but not throughout its extent. Rockaway quarry, the small limestone hill on the south side of Rockaway Beach, and the

Royce quarry are in well-formed synclines. Farther southeast the limestone is interbedded with Franciscan sandstone. Although some of these bodies are associated with faulting, they certainly are not fault slivers and are not floating in plastically deformed sedimentary rocks.

There appears to be a relationship between thrusting and limestone zones where the limestone zones have moderate dips. It may be that limestone defines a zone which is structurally weaker than the massive sandstone surrounding it. Where attitudes of the limestone beds are at high angles to the horizontal, such as in sec. 18, T 4 S., R. 5 W., a minor amount of normal faulting has occurred, but thrusting has not. The first and second limestone-associated zones are characterized by interbedded light or dark-colored chert. The chert beds range in thickness from an inch to 3 or 4 inches. They are concordant with the limestone bedding, as shown by minute zones of pelagic Foraminifera in the limestone. Individual chert layers have been traced for a hundred feet or more in many places. In these places, the thickness remains uniform. In certain localities the limestone has been plastically deformed, and the chert bands, because of their brittleness, have been crushed and formed into discontinuous blebs.

Similarity of discontinuous outcrops of limestone does not necessarily imply that the outcrops were at one time part of a continuous deposit. Instead, where the limestone is associated with sandstones and basalt flows, as in sec. 18, T. 4 S., R. 5 W., there is a suggestion that chemically deposited limestone and chert were laid down on an uneven sea floor. It is suggested that the muds and gels flowed to low flat areas and solidified into beds of essentially uniform thickness.

Although the author is hesitant to attribute the formation of the chert to submarine volcanic springs, he can find no other reasonable explanation at the present time. Silica is known to be abundantly deposited with spilitic lavas throughout the world, and is considered to be a syngenetic sediment, transported by warm waters associated with the tuffs and flows (Davis, 1920; Van Hise, 1911; Taliaferro and Hudson, 1943; Park, 1946; Glassner, 1949). It seems improbable that the Calera limestone has originated from an entirely different source where it is so intimately related to chert. Kania (1929) has shown that agitation and heating of sea water during submarine



Photo 1. Angular unconformity between the Paleocene (above) and the Upper Cretaceous rocks (beneath); view east from north side of San Pedro Point.



Photo 2. San Pedro Rock and its relationship to the mainland. The strata are of Late Cretaceous age and are overturned to the north.

eruption will cause precipitation of limestone in great quantities. Calcite amygdules in the Franciscan basalt of this area testify to the abundance of calcium carbonate in late deuteritic fluids.

A third limestone zone has been found associated only with basalt. Little or no chert accompanies this limestone, which is made up largely of broken tests of organisms. The major constituents are fragments of gastropods, pelecypods, brachiopods, echinoid spines, and tests of unidentified organisms that may be some species of large foraminifera. None of the fragments has been identified as being indicative of any particular geologic age.

The color of the limestone ranges from light-drab gray to dark gray. Weathered surfaces are light gray. Pyrite and a few detrital grains of the surrounding rock units are all that have been found as residues in two acid-treated random samples (Patin and Miranda, 1946).

The thickness of the Calera limestone varies considerably. The maximum thickness in this area, found at Rockaway Beach, is 200 feet. The limestone body is in the form of a syncline which pitches northwest at an angle of 45 degrees. Interbedded basaltic tuff is associated with the mass. The limestone is more resistant to erosion than the surrounding sediments. As a result it is frequently found on crests of hills. Because the limestone includes silica, solution of lime and reorganization of silica by weathering has formed, in places, an outer case-hardened shell enriched in silica which is very resistant to further weathering.

Chemical analyses of the Calera limestone have been published by Walker (1950). Near the type locality, the limestone contains from 63 to 87 percent CaCO_3 . Silica content ranges as high as 32 percent in the Ken Royce quarry just south of Rockaway Beach. The MgO content is below 1 percent in all samples.

In thin sections the limestone appears dense and extremely fine-grained. Secondary calcite veins are common and the included foraminifera are conspicuous.

Chert. Chert beds of the Franciscan Formation are well known and have been described by Davis (1920). In this area, the chert is widespread, contains some radiolaria, and ranges in color from deep green through white

and red. It is associated with all other sedimentary rocks of the formation, and probably represents a product of volcanic springs. All chert beds in the area are mapped, but whether any group of chert beds represents a single stratigraphic zone is doubtful. These, like the chert within the Calera limestone, are well-bedded and lack detrital constituents—characteristics which suggest gelatinization in an area of minimum clastic deposition.

Basalt. Widespread and extensive volcanism is known to have taken place at the time of deposition of the upper part of the Franciscan. The rocks of this area classed as basalt are of four general types: spilitic basalt, tuff breccia, amygdaloidal basalt, and tuff. Although these four types have individual characteristics, they are so thoroughly mixed with one another, and weathering has been so extreme that they can be separated only in isolated localities.

Spilitic basalt has been found in two localities: along the extreme north border of the area, just above Sharp Park golf course; and near the north arm of Pilarcitos Lake. The rock is composed of laths of oligoclase 2 millimeters long and altered interstitial augite. No olivine is present. Texture is ophitic. The rock is termed basalt because an originally more calcic feldspar is believed to have been changed by spilitization to the fresh-appearing oligoclase.

Tuff breccia is widespread but forms only a small portion of the volume mapped as basalt. It is always accompanied by devitrified basaltic ashy tuff. The ratio of fragments to ash varies considerably. The most accessible outcrop of the breccia is at the north end of the State Highway 1 road cut just north of Vallejo. Here the fragments are angular, and as much as $1\frac{1}{2}$ inches across; the ratio of fragments to ash is about 10:1. In the rock on the north side of the Royce quarry, the fragments are of comparable size but compose only 5 or 10 percent of the mass. The fragments are of extremely fine-grained crystalline material. Augite(?) is present as microlites; no feldspar was identified.

Amygdaloidal basalt is also widespread and is estimated to make up 10 percent of the total basalt of this area. The amygdules are commonly quartz, less com-



FIGURE 3. Thin sections. A. Thin section of basalt tuff from San Andreas Dam. The rock is composed of devitrified glass shards. Alteration rims are shown. Plain polarized light. B. Thin section of a Franciscan graywacke taken from the quarry just north of San Andreas Dam. Within this section are shown quartz (q), oligoclase (o), and rock fragments (r). Crossed nicols. C. Thin section of brecciated granodiorite from near Pilarcitas Lake. The groundmass is not determinable. The minerals shown are oligoclase (o), quartz (q), and orthoclase (ar). Crossed nicols. D. Thin section of the dike rock found along Pilarcitos thrust at Pilarcitos Lake. Augite (a) and labradorite (l) are the chief constituents. Crossed nicols.

monly calcite. Amygdaloidal basalt is more resistant to weathering than the other basalt, hence the beds commonly appear as high areas on ridges, as on the hills west of Vallemar and along the basalt ridge which bears a trail from Sweeney Ridge to Rockaway quarry.

Where weathering has been intense, amygdaloidal basalt is represented by rounded quartz pebbles in a clay soil. In hand specimens of fresh samples, the amygdules are white to light green in color, surrounded by a fine gray, green, or brown glassy groundmass. In thin section, microclites of augite are seen to be the chief crystalline constituent of the groundmass. Where crystallization is nearly complete, augite composes three-fourths of the groundmass. The only plagioclase present is as altered clumps of bytownite(?) laths. Where the majority of the thin section is devitrified glass, augite phenocrysts are found as laths 0.75 millimeter long.

Tuff is estimated to make up 85 percent or more of the basalt of this area. The beds consist of devitrified glass shards and tuff fragments up to the size of a pea. Weathered tuff in hand specimen is brown and waxy in appearance. Schistosity is commonly developed in the more intensely folded areas. Without the aid of a microscope, many specimens are mistaken for sheared and altered serpentine masses. In fresher specimens, some tuff fragments can be distinguished.

A number of thin sections of specimens from the lens-shaped igneous body exposed on the northeast flank of Sweeney Ridge have been studied. The lens is 600 feet thick and is composed entirely of volcanic tuff. The lower 200 feet consists of tuff fragments and crystals having a maximum size of 3 millimeters. The coarser material is at the bottom, grading upward into finer tuffaceous material. The upper 400 feet is composed of devitrified brown glass shards.

Pillow lava, well known in the Franciscan of other localities, is not present in this area.

At least 95 percent of the volcanic products in the Franciscan Formation in this area is estimated to be the result of explosive activity.

Serpentine. The serpentine in the Montara Mountain area is present in both a "slickensided facies" and "massive facies". In small areas of extreme shear, only the slickensided facies is found. Where large bodies of extremely sheared serpentine are present, the slickensided facies includes residual boulders of the massive facies. Where large bodies are present and the shear has not been extreme, the massive facies prevails. Just south of San Andreas Dam a large serpentine mass has been sheared by repeated movements of the San Andreas fault. Here dense compact boulders of serpentine ranging from an inch to several feet in diameter are in a matrix of leafy or scaly serpentine. The boulders are rounded as if rolled during repeated movement along the fault. The matrix is white to light green or blue-green in color and is platy in texture.

A large percentage of the serpentine of the Montara Mountain area is in the form of bastite. The rock is medium-grained in texture, with individual crystals 2 to 4 millimeters in length. Chromite and magnetite are common accessory minerals.

Partially serpentinized peridotite composed of forsterite, enstatite, antigorite, chrysotile, and serphophite commonly is present. Partial serpentinization of these bodies

suggests that the ultrabasic rocks may have originally begun as an intrusion of peridotite and picked up water from the fractured, saturated zones of the Franciscan sediments.

No contact metamorphism has been found associated with serpentine within this area, but glaucophane schist is associated with serpentine on Buri Buri Ridge beyond the limits of the mapped area.

The author concludes that the serpentine in this area is similar and probably equivalent in age to other serpentine belts of the San Francisco peninsula. Intrusion of the serpentine must have taken place at low temperatures as shown by the general lack of metamorphism.

Diabase and Related Dike Rocks. The Franciscan Formation is intruded by many bodies other than serpentine. They are small but are widely distributed and range in composition from quartz diorite porphyry to basalt. They may have come in late in the sequence of deposition of the including sediments or even as post-depositional intrusives, and are commonly found associated with thrusts or other zones of weakness. In places they are found as plugs, but these may have penetrated near to the surface via thrust zones.

Two intrusive masses are of special interest. Along the Pilarcitos thrust, at Pilarcitos Lake, is a white to light gray-green augite-labradorite rock. This was previously mapped as limestone; but in thin section, the rock is found to be composed entirely of calcic labradorite (An_{70}) and colorless augite. This is the only unaltered basic plagioclase recognized by the author within the rocks of Franciscan lithology found in the mapped area. The rock is fresh and unaltered and in this respect is unlike the surrounding sediments. Freshness of the minerals suggests a rather late intrusion and, since this rock is found only along the Pilarcitos thrust, the intrusion probably is post-Paleocene (mid-Miocene?) in age.

An unusual small pluglike body is present on the west side of State Highway 1, just south of Rockaway Beach. The rock stands out on the hillside in a circular pattern. It is very fine grained and extremely altered. In this section, small interlocking masses of albitized oligoclase are seen in a completely altered groundmass. During intrusion, the magmatic body picked up fragments of quartz. This quartz is probably from a plutonic source, for it is distinctly different in character from the quartz fragments found in the Franciscan sandstone beds or in quartz veins.

Age of the Franciscan Formation. The age of the Franciscan Formation has been the subject of much debate in the past and undoubtedly will continue to be in the future. A new criterion for determining the age of this sequence was used after futile attempts had been made by the writer to find diagnostic megafossils. This criterion is based on the evolutionary changes in plant pollen from Jurassic to Cretaceous time. Plant pollen is very resistant to strong acids and to weak bases; it is rarely destroyed in sediments, and is recoverable from them. It is the writer's belief that fossil pollen may someday prove to be one of the most valuable criteria for correlation of sediments, because of its resistance to destruction and because it is deposited from the air and therefore is present in most sediments, both terrestrial and marine.

Six numbered but otherwise unidentified samples of shale and limestone were processed by the writer and sent to H. P. Hansen.² Sample number 4 was a reference standard taken from the basal Paskenta, in Napa County, which contained *Buchia piochii* and *Buchia crassacolis*. The paleontological zone defined by the overlap of these two index fossils is generally accepted as being near or at the Jurassic-Cretaceous boundary. Of the five Franciscan samples, three contained insufficient material for identification. Hansen identified pollen present in the Franciscan sediments as belonging to the angiosperm families Betulaceae, Chenopodiaceae, and (?) Compositae.

An interpretation of the identifications by Dr. Hansen has been prepared by Ralph W. Chaney³ as follows:

The content of slide No. 4 (the standard sample), showing ferns and conifers, is consistent with the position at, or slightly above, the Jurassic-Cretaceous boundary.

The content of slide No. 6 (the Colera limestone from Rockaway Beach) is indicative of Upper Cretaceous age in terms of our present knowledge. There is no record of *Alnus*, and no record of its family, the Betulaceae, before the end of Lower Cretaceous or the beginning of Upper Cretaceous time; the Chenopodiaceae is an advanced family of angiosperms which, to my knowledge, has never previously been reported in any part of the Cretaceous, and would scarcely be expected to occur in rocks older than Upper Cretaceous.

Slide No. 2 (which is shale from the quarry just north of the San Andreas Dam) contains the doubtful record of Compositae. Here again is a family not recorded prior to Upper Cretaceous time. It seems improbable that the material in this slide and in slide No. 6 is older than Upper Cretaceous.

Thin sections of the Calera limestone at the type locality were made for study. The foraminiferal genus *Globotruncana*, which has been recognized in the Calera limestone of Santa Clara (Glassner, 1949; Thalmann, 1942; Cushman, 1948) and in the New Almaden district, is abundant in both of the lower zones described in this paper as the Calera limestone.

Arthur S. Campbell⁴ has prepared the following statement for this paper concerning the significance of *Globotruncana* in the type area of the Calera limestone:

Two thin sections of the Colera limestone member of the Franciscan exposed at Rockaway Beach near the city of San Francisco were examined for foraminifera. These organisms have long been known to occur in this formation but have always been considered too distorted and broken for recognition. In both slides, a flood of well-preserved *Globotruncana* Cushman 1927 was found. It is a single-keeled species with affinity to the European form known as *G. appenninica* Renz, and, like it, is single-keeled and lenticular in cross-section. The species is found in the Cenomanian, and rarely and doubtfully, in the lower Turonian. Except as found in later reworked sediments even as far up as to the middle Cenozoic, the genus *Globotruncana* is exclusive to Cretaceous rocks and different species occur in different stages and are characteristic of them. The genus is worldwide and includes, according to Glassner, some of the most valuable stratigraphic index fossils of the Upper Cretaceous. The genus is generally considered to be pelagic and was a dweller in the upper levels of the sea.

Besides *Globotruncana* in great numbers, a few vague remains of a possible *Nodosoria* were found. Tholmann records a species similar to the one described above in the Colera limestone of the Permanente quarry in Santa Clara County (Pala Alto quadrangle). He also records a double-keeled species, *G. linneiana* (d'Orbigny) in the same material and he believes, therefore, that the Franciscan of this area must not be older than Turanian nor younger than Santonian.

An ammonite has recently been found in a Franciscan cliff section in James D. Phelan State Park in San Francisco. It has been identified by Siemon W. Muller, and independently by J. Wyatt Durham, as a species of the genus *Douvilleicerias*, and has been assigned to the Albion stage of the late Lower Cretaceous (Schlocker, et al., 1954).

That at least some of the sediments of Franciscan lithology in the San Francisco peninsula are of mid-Cretaceous age can hardly be denied when the paleontological evidence of three independent types agrees so closely. This in no way implies that Franciscan strata of other localities are not of Jurassic age; in fact, indisputable evidence has been put forth by Taliaferro, Durham, and others that part of the Franciscan is of Jurassic age. The type Franciscan of this area has previously been assigned to the Jurassic because of its lithologic similarity to Franciscan of other regions of known Jurassic age.

The lithologic similarity of the various areas is marked, particularly where glaucophane schist, serpentine, and products of widespread volcanism are displayed in the Franciscan Formation. It would appear that the conditions causing the formation of the peculiar Franciscan lithologic types persisted, locally at least, from Upper Jurassic time until at least the early part of the Upper Cretaceous.

Late Upper Cretaceous Rocks

Sandstone and shale characterize the unnamed late Upper Cretaceous strata of this area throughout their extent. The sediments are present at San Pedro Point, and crop out in a discontinuous band southeastward along the northeast flank of Montara Mountain. At San Pedro Point they have been referred to as the San Pedro shales (Crandall, 1907); but, as Paleocene strata were included at the time this unit was named, and as the name is preoccupied, the term San Pedro shales is not used herein.

The sandstone and shale beds average from 4 to 12 inches in thickness. The shale is light gray to black, deepening in color with increase in moisture. Sandstone beds are much like those of the Franciscan graywacke described earlier in this paper. Calcic albite (An 7 to 9) is present as well as oligoclase, and rock fragments make up 50 percent or more of the sample. Quartz is angular, and secondary calcite is present as a cement. Muscovite and biotite are present, but not augite.

Tracks of organisms are abundant on the exposed dipslopes seen in road cuts and cliff sections. Fossils are rare, however, and only two have been found which are satisfactory for an age determination.

The Cretaceous age of these sediments has been established by an ammonite cast found just north of San Pedro Point by Olaf P. Jenkins. Leslie E. Wilson of San Mateo Junior College has found a well-preserved *Mesalium*, at the same locality, identified as *M. martinezensis*. The writer believes that it is probably a late Upper Cretaceous form. An Upper Cretaceous age has thus been assigned until evidence is given to the contrary.

A comparison of the weathering of these sediments (then thought to be the lower part of the Franciscan) with those found north of San Pedro Valley (Franciscan) was brought out by Fairbanks in 1897. He noted that the sediments at San Pedro Point weather in huge blocks

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Photo 3. View of the mainland from San Pedro Rock, showing Upper Cretaceous (left) and Paleocene (right) rocks. Strata in the foreground are slightly overturned; those in the background (right) are overturned, and those in the background (left) are in normal order.

which are worn down and rounded by the surf. The (Franciscan) strata, on the other hand, he noticed, weather into small angular fragments. The small size he attributed to regional crushing which apparently did not affect the (Upper Cretaceous) strata. He thought that the rocks at San Pedro Point were raised above sea level shortly after deposition and their compaction resulted mainly from pressure during folding.

There is one small area along the north side of the Shelter Cove peninsula where conglomeratic sandstone is seen in the late Upper Cretaceous formation. The pebbles are rounded, and are composed chiefly of biotite granite, mica schist, and black slate. No identifiable Franciscan debris was found in the beds.

The total thickness of the late Upper Cretaceous sediments is unknown, as the base of the formation is nowhere exposed. A tentative minimum thickness has been set at 2500 feet. The strata appear to thin in a southeasterly direction, as is indicated in the accompanying cross sections. This appearance may be fallacious, however, because of the increase of thrusting activity in that direction.

The unconformable relationship of the late Upper Cretaceous strata with those of the overlying Paleocene is clearly shown in a vertical road cut 1 mile south of San Pedro Valley on State Highway 1, and along the cliff section on the north flank of San Pedro Point. The rela-

tionship of the late Upper Cretaceous rocks to those of the Franciscan in this area is uncertain as they are exposed in contact only along the Pilarcitos fault. However, the lack of intrusive serpentine and diabase in the later sediments, which are common to the Franciscan, suggests an unconformable relationship.

Paleocene Rocks

The unnamed Paleocene formation of the San Pedro area is well known from the work of Lawson (1895, 1914) and Dickerson (1914). These rocks were originally thought (Lawson, 1895) to underlie the Franciscan Formation. Mineralogically, they are similar to Franciscan graywacke and in some places they can be differentiated from the late Upper Cretaceous rocks only with great difficulty.

The Paleocene beds of the Montara Mountain quadrangle form a continuous band from San Pedro Point southeastward past Pilarcitos Lake along the northeast flank of Montara Mountain. They comprise a discontinuous basal layer of coarse conglomerate, followed by coarse-grained sandstone, and then alternating sandstone and shale beds like those in the late Upper Cretaceous formation beneath. Local coarse sandstone and conglomerate are in places found interbedded in the Paleocene strata above the base.



Photo 4. Overturned Upper Cretaceous strata. Photo was taken from the position marked (x) in photo 3. Crushed Paleocene sandstone can be seen in the extreme right.

Photo 5. Gneissic boulder from the Sur series terrane in Paleocene basol conglomerate.



The basal conglomerate of the Paleocene unit crops out along the cliff section just north of Devil's Slide, at San Pedro Point, in various places on the hillsides flanking the south side of San Pedro Valley, and in the Pilarcitos Lake area, as indicated on the accompanying geologic map. At Pilarcitos Lake, the conglomerate is made up of boulders, chiefly of biotite and muscovite granite, and minor amounts of Franciscan debris. The conglomerate is not exposed on the crest of Whiting Ridge, but boulders of it have been found which have washed down into the extreme eastern end of San Pedro Valley. These are also predominately mica granite. Farther to the west, boulders of Sur Series material accompany the granitic type boulders and Franciscan debris. The largest boulders are granitic material similar to that of the Montara granodiorite. They are found in the most western exposures; there, some of them are as much as 5 feet in diameter. Others, of smaller dimensions, are composed of granitic material (unlike that of the Montara type material), hornblende diorite (similar to that found intruding the Montara mass), hornblende gneiss and muscovite gneiss and schist (Sur Series material), red and green

chert (Franciscan debris), quartzite, limestone, and sandstone and shale.

The thickness of the conglomerate ranges from 160 feet near Devil's Slide to 4 feet on the tip of San Pedro Point. The conglomerate is always poorly sorted and poorly bedded; a matrix may be lacking, or made up of coarse sand or pebbles.

The sandstone beds overlying the conglomerate are coarse-to-fine grained and are again principally of the same mineralogy as the late Upper Cretaceous and Franciscan sandstones. In the coarser sandstone beds, rock fragments may make up half of the sample; some fragments were identified as Franciscan basalt. Quartz grains are angular.

The interbedded shale is light gray to black, deepening in color when wet. In some places the Paleocene shale beds are limy and weather yellow. Many of them show graded bedding.

Fossil trails are abundant on dip-slopes of shale beds but the fossils themselves are very rare. Fossils have been found, however, in the coarse sandstone southwest of San Pedro at an elevation of 350 feet. The matrix is friable



Photo 6. Paleocene basol conglomerate in a vertical road cut southeast of San Pedro Point. Boulder in the photo is 4½ feet across.



Photo 7. State Highway 1 covered by a landslide (January 1951) along the cliff south of Devil's Slide. Landslide material is of Paleocene age.

and the fossils are not well preserved. The Paleocene age of these sediments is based on the identification of fossils by Dickerson (1914) who concluded that they are of the same age as the type Martinez Formation in the East Bay. Abundant foraminifera were found in a concretion just south of San Pedro Point but could not be prepared for identification.

The Paleocene sediments overlie the late Upper Cretaceous sediments with an obvious angular unconformity. Their relation to the Franciscan sandstone beds which they overlie on Pedro Mountain is not clear. Neither is the relationship between the Paleocene strata and the granodiorite clear; post-Paleocene shearing has obliterated any original sedimentary contact in the Pilarcitos Lake area. On Whiting Ridge a normal fault has dropped the Paleocene away from the granodiorite. Along the sea cliff near Devil's Slide, undated shale lies between the conglomerate of the Paleocene and the granitic basement.

STRUCTURAL GEOLOGY

As in other regions of the California Coast Ranges, many of the structures of this area are broken beyond recognition; folding and faulting of at least three ages are present. Though it is impossible to determine accurate time relationships between the various movements

in Cretaceous time, it is known that the sum of these movements had a profound effect in the shaping of the Coast Ranges.

Folding

Folds, in the Franciscan rocks, appear as broad, open anticlines and synclines with superimposed tight folds of small dimensions. They are difficult to map because of the massiveness of the sandstones, the widespread crushed nature of the sediments, and the general lack of suitable horizons for structural references. During folding, differential competency of the sandstone and basalt caused the rocks to form into complicated en echelon pitching folds. For example, Sawyer Ridge, shown in the southeastern part of the map, is a gentle syncline pitching 50° S. In a northwesterly direction, this downfold is gradually replaced by a slightly offset syncline pitching to the north. Folds in basalt were determined by correlating characteristic tuff beds because the dips and strikes, which are few in number, were believed to be local and untrustworthy in most cases. Folding in limestone members is usually apparent because of their well-bedded nature. The limestone mass at Rockaway Beach is in a broad syncline which pitches 45° NW. Tight folds, similar to those described within the sandstone beds, are superimposed on the limbs of this syncline.

Photo 8. Local contortions in Paleocene strata on cliff face north of Devil's Slide; view northeast. Lighter colored beds are limy. All beds are overturned toward the north.



Other limestone bodies are folded in a like manner, and some are faulted throughout.

It should be noted that the folds in the Franciscan Formation of the northwest and southeast portions of the map are similar in magnitude, despite the more intense diastrophism in the southeast portion. This suggests that folding was a preliminary, regional feature, and that the widespread thrusting of the rocks occurred at a later date.

San Pedro Syncline. The complexly faulted, folded, and overturned sediments of Upper Cretaceous and Paleocene age of the Shelter Cove-San Pedro Point-Devil's Slide area have long been known as the "San Pedro syncline". Cross sections A'-A, B'-B, and C'-C on plate 2 show the progressive changes of structure inland from San Pedro Point. Structures which are overturned to the west are vertical along the strike to the east. Normal faults are common in the late Upper Cretaceous and Paleocene sediments accompanying the folding and bedding thrusts. The thrust shown in section C'-C is seen only at Devil's Slide and has been the controlling element of the northward slope of the slide. It may be responsible for the position of the Franciscan sedimentary rocks which are found on Pedro Mountain. The age of this thrust is not known. Movement may have occurred long before Paleocene time, or at the time of folding of the Paleocene strata.



Photo 9. A minor fault within the Paleocene rocks. Photo was taken at the point where State Highway 1 first reaches the sea cliff south of San Pedro Valley.

Faulting

Faults are of many types. Thrust faults are the most common major faults; normal faults, although present in great numbers, are less important. Rotational shear, strike-slip, and tear faults are also present. Like folds, faults are difficult to map in crushed massive beds. Commonly, however, serpentine or other intrusives crop out along the fault planes and help define them. In some cases, shear zones crop out on the surface.

Thrust Faulting. Thrusting in the Franciscan rocks has occurred in areas structurally weakened by previous folding, and occurs in zones of limestone and shale. In later formations, thrusting has been principally in the form of bedding thrusts.

The San Mateo thrust appears to be an offshoot of the San Andreas fault system and is exposed along the east side of San Mateo Creek. Just north of sec. 28, T. 4 S., R. 5 W., it branches and dies out. The thrust is expressed on the surface by intermittent exposures of fault gouge or serpentine. Where it crosses Pilarcitos Road in sec. 17, slaty fault gouge containing Franciscan sandstone boulders as much as 4 feet in diameter is present. The sandstone is petrographically identical to that found in the quarry just north of San Andreas Dam. The San Mateo thrust, like all of the major thrusts of this region, dips northeastward.

The Spring Valley thrust is a similar type of fault which joins the Pilarcitos thrust a few hundred feet south of Pilarcitos Lake. Feldspar porphyry dike rocks, with phenocrysts as much as half an inch across, are associated with it. It, like the San Mateo thrust, dies out in a northwesterly direction.

The unnamed thrust which is shown on the geologic map extending from Rockaway Beach along the hillside north of San Pedro Valley is unlike the other thrusts in that its shear zone widens to the northwest. It is well exposed in the road cut south of Rockaway Beach. The thrust zone dips about 40° N. and consists of 200 to 300 feet of sheared sandstone, shale, greenstone, basalt, and serpentine. Sandstone and greenstone boulders several feet in diameter are present. Some of them were well rounded during movement of the thrust. On the hillside 100 yards to the southeast, the Franciscan sandstone has been weathered to considerable depth and displays no surface indication of the thrust. Many important thrusts are probably never seen in the Franciscan rocks because of surface weathering.

Walker (1950) in his recent work on the Calera limestone, has drawn a fault through the Royce quarry which he joins with the Pilarcitos thrust in the extreme eastern end of San Pedro Valley. The writer was unable to locate it except possibly at the old Royce quarry and perhaps farther northwest where small serpentine intrusions are mapped.

The Pilarcitos thrust is described by Bailey Willis as a rotational shear. He considered it to be a branch of the San Andreas fault which diverges from the rift zone about 20 miles south of Pilarcitos Lake, and runs parallel to the rift northward to Montara Mountain where it bends to the west and follows along the north flank of the granitic mass. According to Taliaferro (1943) the Pilarcitos thrust is a fault formed first in the Eocene,

Photo 10. Thrust fault through granodiorite at Devil's Slide. The attitude of the thrust plane is east-west with a north dip of 40° . Granitic material above the thrust is severely fractured. Below the thrust the rock is more massive.



Subsidence

The San Pedro and Calera Valleys display the features of the Golden Gate subsidence (Lawson, 1894). Lawson assumed the total sag at the Golden Gate to be 378 feet. Valley profiles have been drawn across San Pedro Valley which show it to be aggraded up to 250 feet above sea level in its upper reaches. At the mouth of the valley, sediments close to 500 feet thick are calculated to have filled the valley beneath sea level.

GEOLOGIC HISTORY

Too little is known of the history of Montara Mountain and of the ancient crystalline rocks to the west for the writer to make any statement regarding the many pre-Franciscan diastrophic events they probably experienced. It is known, however, that they were folded, metamorphosed, and intruded prior to the deposition of sediments of the Franciscan Formation. Old crystalline rocks (Sur Series?) contributed the rock fragments which make up a large portion of the Franciscan.

Krynine (1935) and others have shown that feldspar content of sandstones is not a direct index of climate. If it is an index to the tectonic intensity, however, as Pettijohn (1949) states, the rate of erosion from the land masses of mid-Cretaceous time must have been very fast. For example, if the rock fragmental material of the Franciscan graywacke, assumed to be debris of former sediments, is subtracted from the total volume of sandstone, the remaining portion represents the detritus of eroded plutonic material. The remaining portion thus contains nearly 50 percent oligoclase. The writer is not prepared to explain the relatively low content of alkali feldspar in the sandstone. Weathered orthoclase may be mistaken for rock fragmental material, but in any case the total feldspar content of the plutonic fraction is high.

No evidence has been found in this area to indicate a coarsening of Franciscan sediments in any particular direction. The later sandstone beds of the sequence appear to become more tuffaceous in the northwest, perhaps suggesting the presence of a land mass in that direction. Certainly there was a rugged land mass to the west, from which most of the graywacke was derived. Support for the existence of this terrain is found in the later Paleo-

probably as a normal fault, after deposition of the Paleocene rocks and before deposition of the lower Miocene Vaqueros formation. The evidence in this area shows movement of the Pilarcitos thrust merely as post-Paleocene when Franciscan rocks were thrust over the late Upper Cretaceous and Paleocene strata. This thrusting was probably accompanied by the intrusion of the augite-labradorite rock described earlier in this paper. The plane of the Pilarcitos fault dips 40° NE. at Pilarcitos Lake.

Normal Faulting. Normal faults everywhere accompany folding and crushing of the sedimentary and volcanic rocks. Most of them are of minor importance, but the sum of their movements has been an important factor in determining the structure of the area.

Paleocene rocks have been dropped relative to the granodiorite on Whiting Ridge by movement along the Montara fault. A fault scarp is present at this locality, but the extent of the fault is unknown.

Montara Mountain has risen along an east-west normal fault exposed just north of Devil's Slide in the cliff section. It cannot be traced inland very far, but is of the same type, and may be part of the Montara fault.

The fault which cuts across the axis of the limestone syncline at Rockaway Beach is of interest because small quantities of petroleum have penetrated the fault zone and have saturated the adjoining limestone beds. The minimum movement of this fault is 200 feet; the limestone is on the upthrown side.

Strike-Slip Faulting. The San Andreas fault is the only strike-slip fault found within the area studied, but many of the thrust faults undoubtedly had a horizontal component also. The fault zone of the San Andreas, in this area, is vertical, and the movement has been, for the most part, in a horizontal plane. Repeated movement along this fault is displayed in the crushed and sheared rocks within its zone.

Tear Faults. Tear faults are probably common within this area but can rarely be seen. One such fault is on Sweeney Ridge. Here, it is associated with a synclinal structure where the rocks of the southern side of the fault have experienced tighter folding than those on the northern side.

cene sediments. The vertical position of Montara Mountain is unknown during the time of deposition of Franciscan rocks. It undoubtedly acted as a buttress against folding.

Of the Franciscan sedimentary rocks mapped in the area, certainly less than 5 percent, and probably less than 1 percent, is shale. The shale is found locally in what must have been shallow basins on the extensive shelves where the sediments were deposited. Similar low areas below wave base in the Franciscan sea were filled with limestone and associated chert. Anygdaloidal basalt flows poured out on the sea bottom, and agitated and heated the sea water enough so that large volumes of limestone were precipitated. The associated chert came from silicious springs active at that time. Volcanic explosions then blew out solidified fissure materials as coarse to fine lapilli. As explosive action continued, huge quantities of basaltic magma were blown out and glass shards formed. They, like the larger tuff fragments, have been compacted by subsequent regional pressures. Where diastrophism has been extreme, they and the basalt flows display fracturing and brecciation.

Later, folding and faulting were accompanied by intrusions of partially serpentinized peridotite, and diabase. In the process of serpentinization, the ultrabasic rocks increased in volume two or three fold. This increase in volume may be significant in the emplacement, and hence, may have caused the shearing of the serpentine bodies. The source of all the water required for serpentinization is unknown, but much of it was probably contributed by the saturated sediments which released water to weakened, relatively porous zones formed during preliminary faulting and folding. They are the zones along which peridotite (or serpentine) would be expected to travel.

How much folding and faulting took place before the latest Cretaceous sediments were laid down is not known.⁵ Enough time may have elapsed between the end of Franciscan deposition and the beginning of late Upper Cretaceous time for widespread folding, faulting, and erosion to have taken place. A part of this time is represented, in the area studied, by a significant change in tectonic stability as shown by the absence of volcanic and intrusive rocks in the late Upper Cretaceous strata.

Sediments of late Upper Cretaceous age, like the Franciscan sediments, were laid down in a geosynclinal environment. The tracks of many marine organisms have been preserved in the strata. Shortly after deposition of the alternating sandstone and shale of late Upper Cretaceous time, the strata were raised above sea level and eroded. Tilting prior to Paleocene deposition was at least 35° in some localities.

The strata were again submerged, and a rugged terrain contributed boulders, sand, and shale to the subsequent Paleocene sediments. Beaches of early Paleocene time must have been similar in many respects to those of today in this area. Alternating bouldery and sandy beaches were present, cliffs contributed blocks of shale, and a land mass to the west contributed coarse crystalline detritus from the old Sur series. Gradually the conglomerate gave way to coarse sand and then to alternating sandstone and shale very similar to those laid down in the preceding period.

⁵ During an orogeny (Santa Lucian or Taliaferro?) in mid-Upper Cretaceous the Montara granodiorite may have been intruded into Franciscan and older rock formations.—Ed.

Montara Mountain during late Upper Cretaceous and Paleocene time probably was an oval, dome-shaped mass only slightly, if at all, above sea level. To the west there was a land mass, probably higher and more rugged. Montara Mountain probably contributed Franciscan debris and granitic debris; the land mass to the west contributed debris from slate, schist, gneiss, intrusive rocks, and probably Franciscan rocks, as well as granitic materials. The two mountain masses were either separated from one another by a shallow seaway, or there was a deep cove in the coast line about where Devil's Slide is now. Paleocene sediments, and the latest Upper Cretaceous sediments before them, lapped onto and around the end of the dome-shaped Montara mass.

Sometime after the deposition of the Paleocene strata, compressional forces again prevailed. This, in all probability, was the beginning of the most severe thrusting of this region; thrusting occurred in Franciscan strata along old thrust faults. Crushing of the granitic masses near Pilarcitos Lake took place at this time. These may have been buried masses which were forced up by the extreme compressional forces acting against the granitic basement. The Upper Cretaceous and Paleocene strata which were beyond the western end of Montara Mountain were less competent and had no igneous mass to buttress them. Hence, the folding there was more severe; and many of the folds were overturned, whereas folds farther east were not.

Whether the Franciscan, late Upper Cretaceous, or Paleocene rocks were actually thrust farther onto the granite is not clear. Lawson (1894) thought the absence of the Paleocene conglomerate along parts of the Paleocene-granite contact indicated a fault in which the coarse constituents were dropped out of view. The Montara fault, which is exposed on Whiting Ridge, is of this nature, but its extent is not known.

During or shortly after the post-Paleocene folding and faulting, the land mass to the west was submerged, and Montara Mountain began to rise. This rise has taken place along a normal fault which has broken through the overturned syncline 2800 feet north of Devil's Slide. Portions of Upper Cretaceous and Paleocene strata now slide down the northwest slope of the dome-shaped Montara mass as support is constantly eroded from beneath by the rough surf.

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Topography from U.S. Geological Survey
Montara Mountain quadrangle.

SYMBOLS

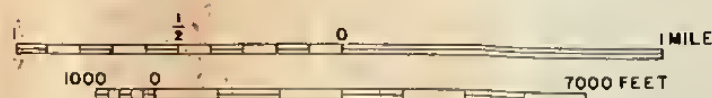
—	Contact	+	Vertical beds
- - -	Indefinite contact	U	Schistosity
- - - - -	Fault (dashed where inferred dotted where concealed)	—+—	Axis of plunging anticline
- - - - -	Fault zone	—+—	Axis of plunging syncline
	Land slide	∩	Overturned anticline
+	Normal attitude	∩	Overturned syncline
+	Overturned beds	x	Quarry

EXPLANATION

RECENT	Qol	Alluvium
PALEOCENE	Tpa	Sandstone and shale
UPPER CRETACEOUS	Ku	Sandstone and shale
CRETACEOUS	+grd+	Montara granodiorite
MIDDLE CRETACEOUS	d	Diabase etc.
	sp	Serpentine
	Kb	Basalt
	Kch	Chert
	Kco	Cofre limestone
	Kf	Sandstone and shale

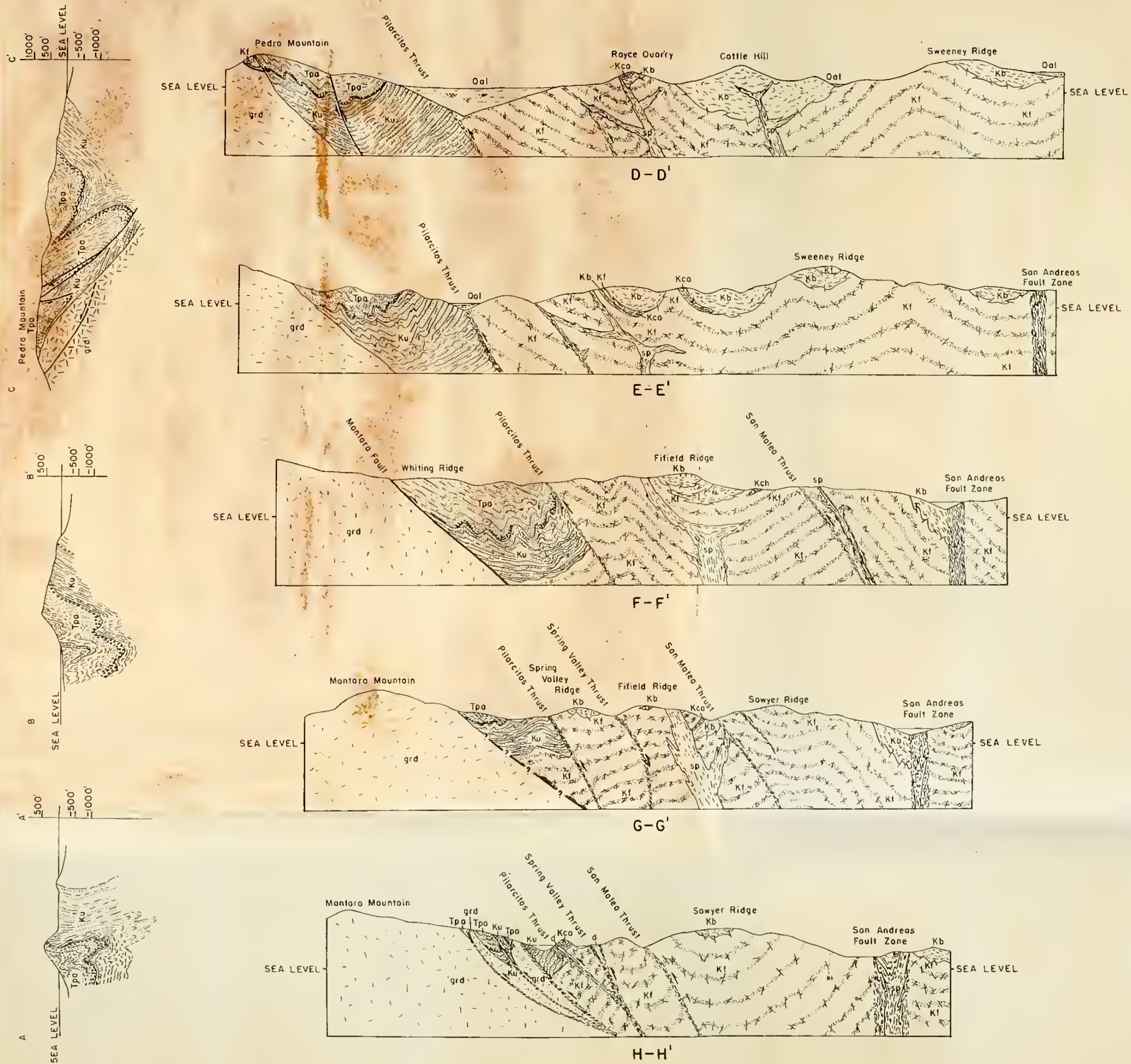
GEOLOGIC MAP OF PART OF THE MONTARA MOUNTAIN QUADRANGLE

GEOLOGY MAPPED BY R.L. DARROW, 1951



CONTOUR INTERVAL 25 FEET
DATUM IS MEAN SEA LEVEL

GEOLOGIC STRUCTURE SECTIONS OF PART OF THE MONTARA MOUNTAIN QUADRANGLE, CALIFORNIA



EXPLANATION

	Alluvium		Serpentine
	Paleocene sandstone and shale		Basalt
	Upper Cretaceous sandstone and shale		Chert
	Montara granodiorite		Calera limestone
	Diabase etc.		Sandstone and shale



R. L. DARROW, 1951

